Rocket Design for the Future

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Boeing - Seattle
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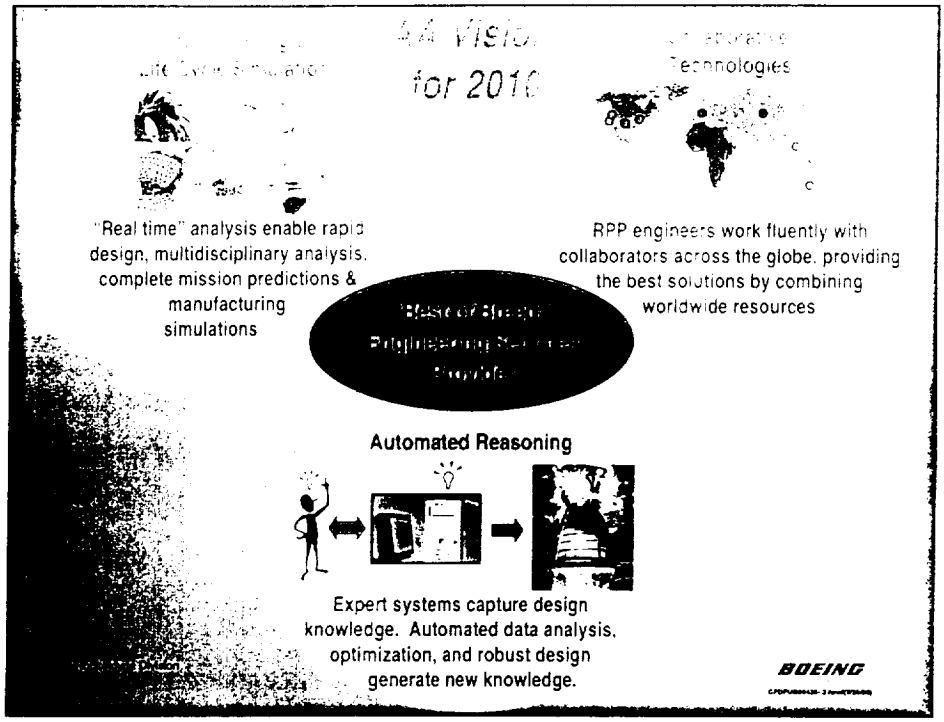
AGENDA

- Vision
- Approach
  - Optimization and Robust Design
  - Knowledge Based Systems
  - Collaborative Technologies
- Examples
- Summary



Expert Systems and MDO Capture and Expand Design Knowledge

- **Approach**
  - **Integrate design technologies into state of the art design systems**
    - Reduce time & cost required to create new products
    - Capture engineering expertise
    - Provide users with design environments customized to their problem
  - **Design technology thrusts:**
    - Optimization and Robust Design
    - Expert Systems
    - Collaborative Technologies

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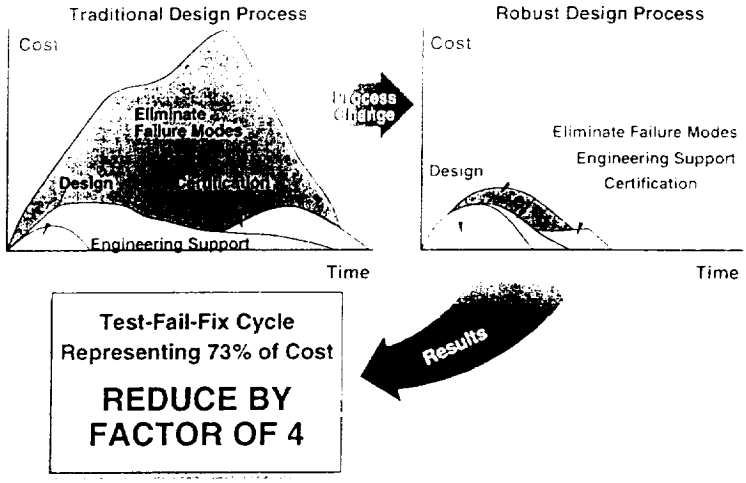
Technology Thrust: Robust Design

Challenge: Reduce Development Cost



Test-Fail-Fix Cycle Representing 73% of Cost

REDUCE BY FACTOR OF 4

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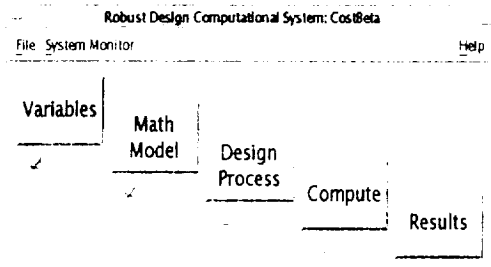
Robust Design Computation System

RDCS Features

- Workflow aids robust design
- Variables from databases
- Math models include standardized and automated analysis processes
- Various robust design processes available
- Distributed Computing



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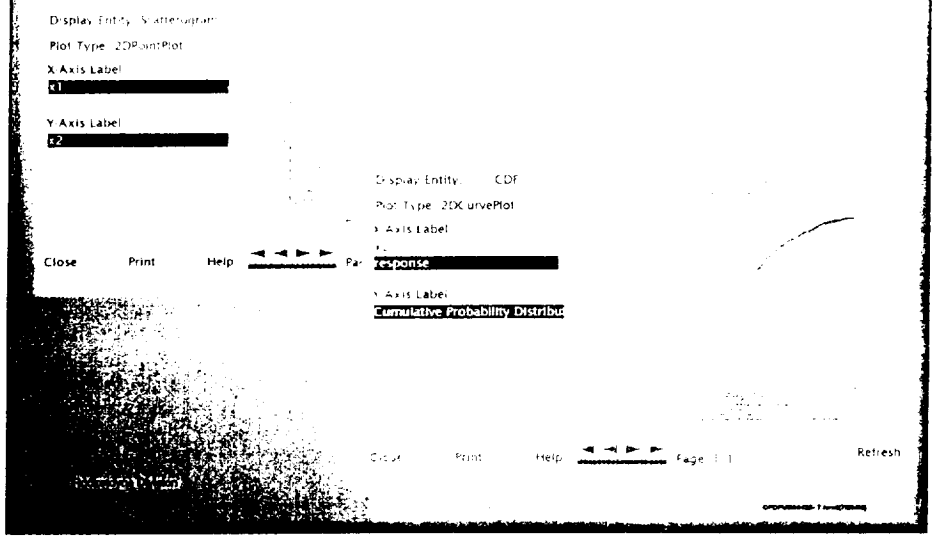
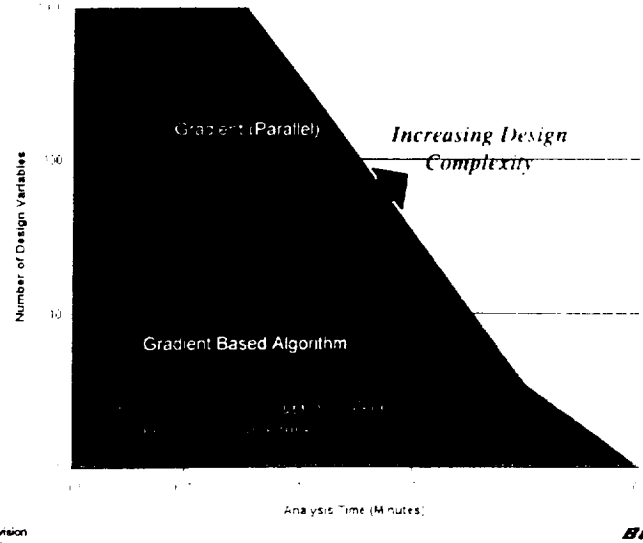
RDCS Probabilistic Analysis - Results



Technology Thrust: Optimization

Implement Optimization Tools to Support Increased Design Complexity



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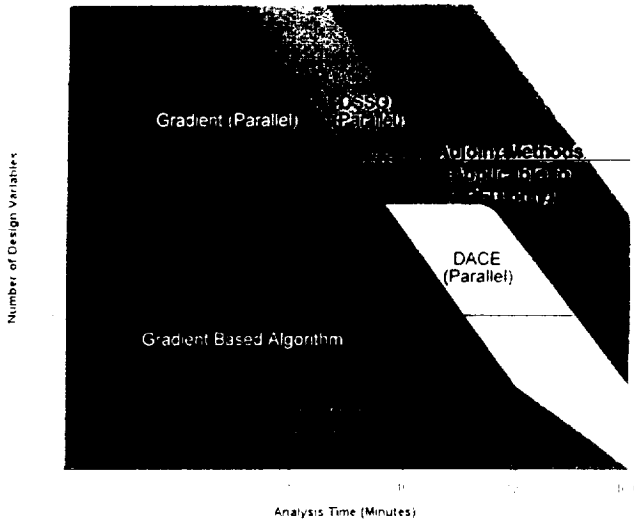

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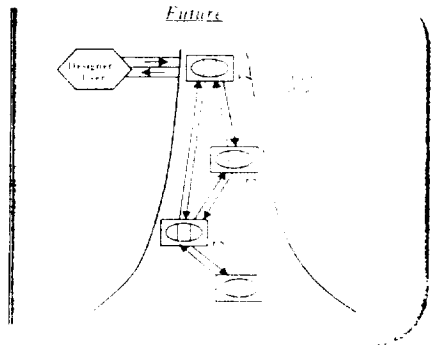
Technology Thrust: Knowledge Based Systems

- **Future role of analysts/designers can become that of owner/developer of expert shells or 'knowledge stations'**
- **The expert shells interact with each other semi-autonomously**



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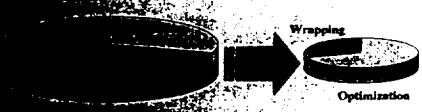
MUMMY Captures & Automates Analysis Expertise

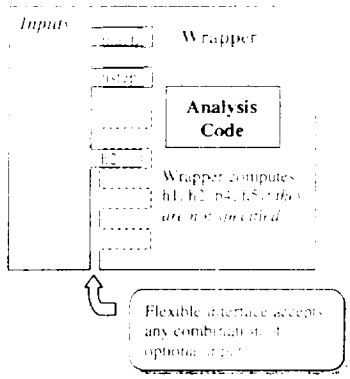
MUMMY Features

- Captures engineering expertise with "Smart Defaults"
  - More efficient optimization
  - More robust analysis code operation
- More flexible interfaces than commercial wrapping software

MUMMY reduces the cost of automation ("Wrapping")



MUMMY Modules are Flexible



Flexible interface accepts any combination of options

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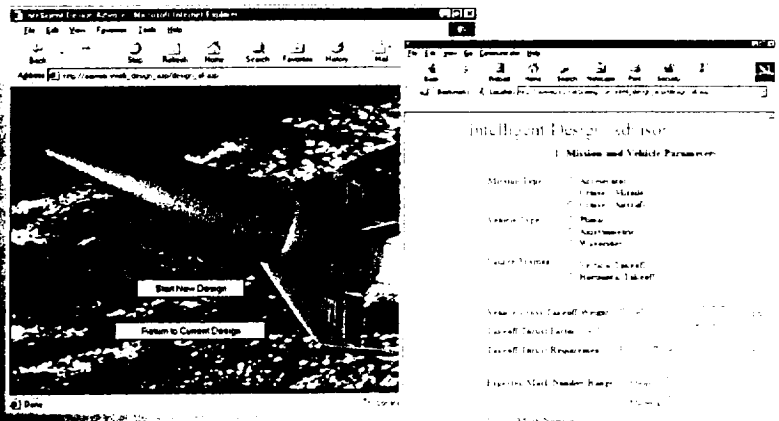
Intelligent Design Advisor Captures Hypersonic Propulsion Expertise



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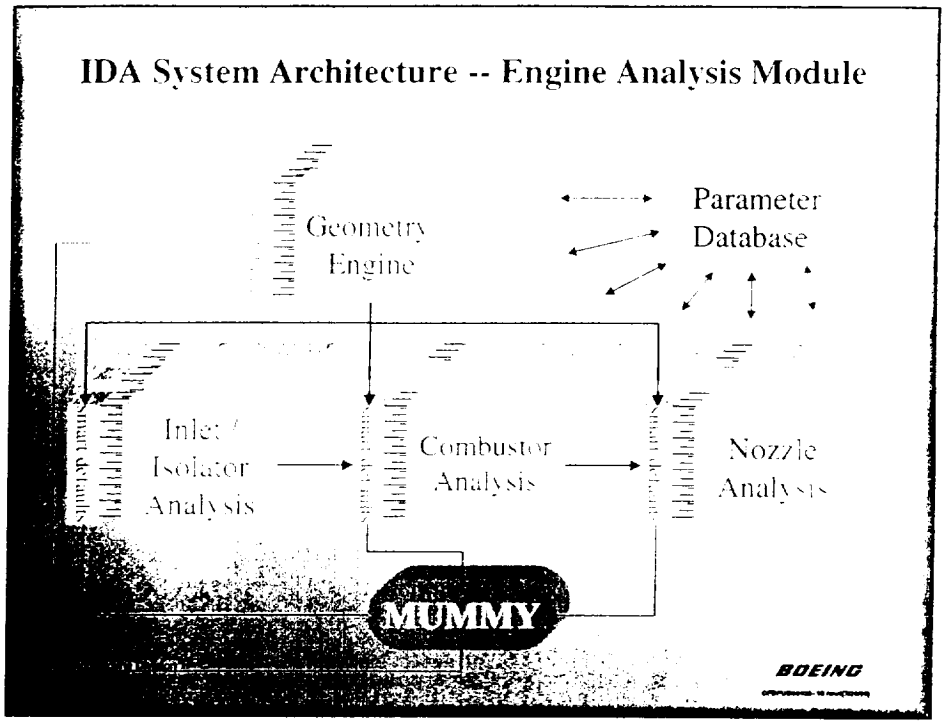
IDA System Architecture -- Engine Analysis Module
Geometry Engine
Parameter Database
Inlet / Isolator Analysis
Combustor Analysis
Nozzle Analysis
MUMMY
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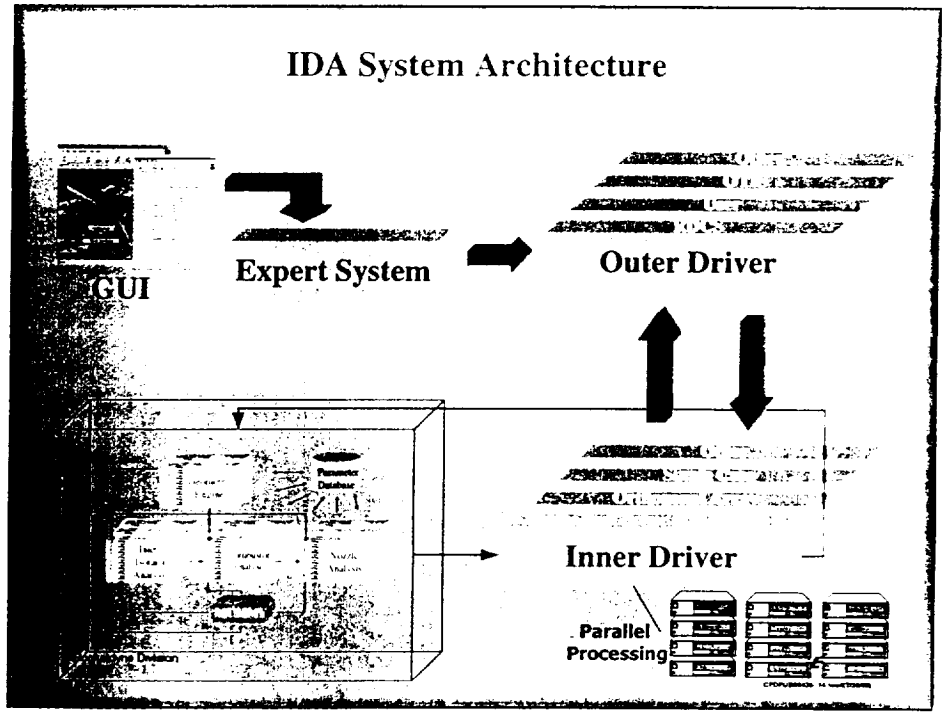
IDA System Architecture
GUI
Expert System
Outer Driver
Inner Driver
Parallel Processing

Technology Thrust: Collaborative Technologies

- Collaborative optimization algorithms
  - Enable MDO among geographically dispersed teams
  - Address MDO problems of unprecedented size and complexity
- Internet-Based Parallel Processing Tools
  - Enable controlled access among design team members to geographically dispersed computational resources
  - Facilitate effective use of available computational resources for fast turnaround (e.g., parallel processing)
- Virtual collocation of personnel

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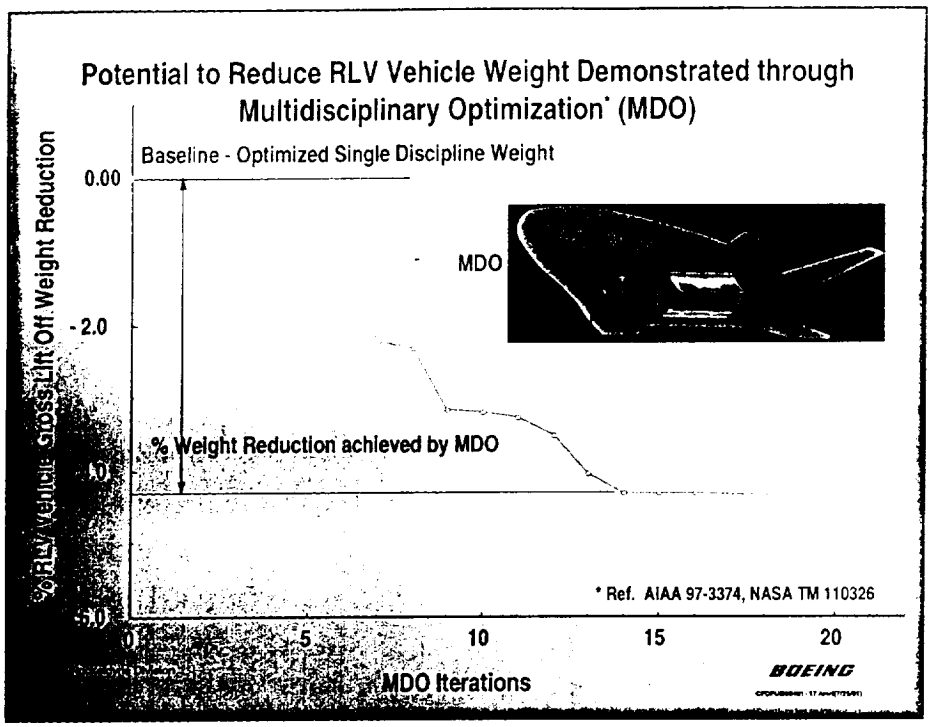
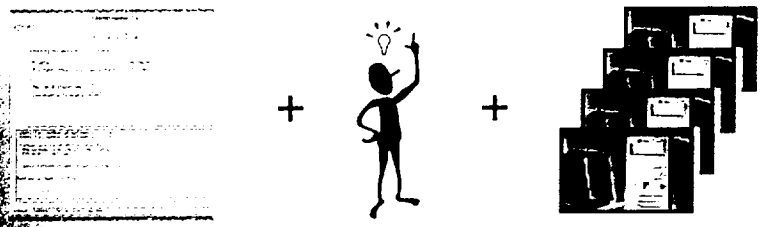
Potential to Reduce RLV Vehicle Weight Demonstrated through Multidisciplinary Optimization* (MDO)



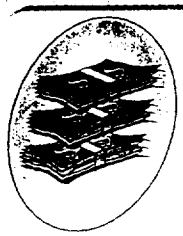
CASINO Reduces Cost and Complexity of Aerospike Design by an Order of Magnitude



GUI & Automation

Captured Design & Analysis Knowledge

Parallel Computing & Optimization



- For 2000:
  - $5M added engineeering value
  - 4000% return on investment in first year
  - 61% improvement in predicted payload-to-ISS

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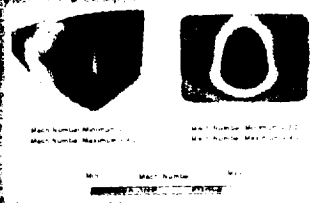
Multidisciplinary Optimization is Now a Design Tool

Tripropellant Nozzle

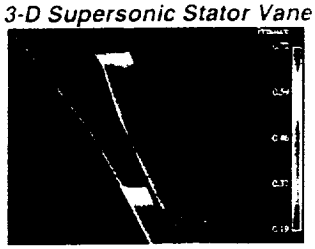
- Maximize thrust and minimize hot spots
- 23% peak heat load reduction, 0.1% thrust improvement

Thruster Nozzle



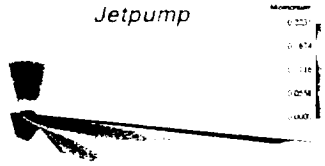
- Maximize Thrust/Wt. ratio
- 16% T/W improvement

3-D Supersonic Stator Vane



- Match target pressure profiles
- 90% improvement achieved

Jetpump



- Maximize efficiency & flow uniformity
- Design cycle time reduced by factor of 3

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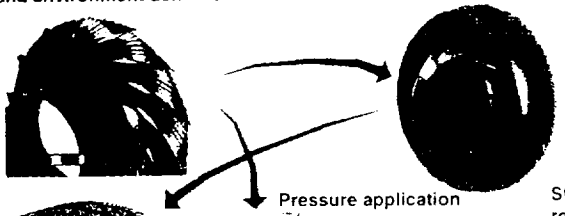
Integrated Development
Multidisciplinary Linked Analysis & Design

Hydrodynamics analysis blade and environment definition

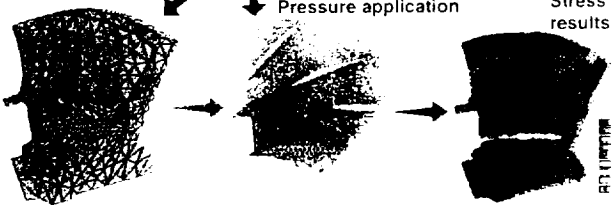
Mechanical design (Pro-E)



Pressure application

Stress results

Stress FE Model (ANSYS)



Impeller Cycle Time Reduced - 6 Months to 1 Week

Rocketdyne Division

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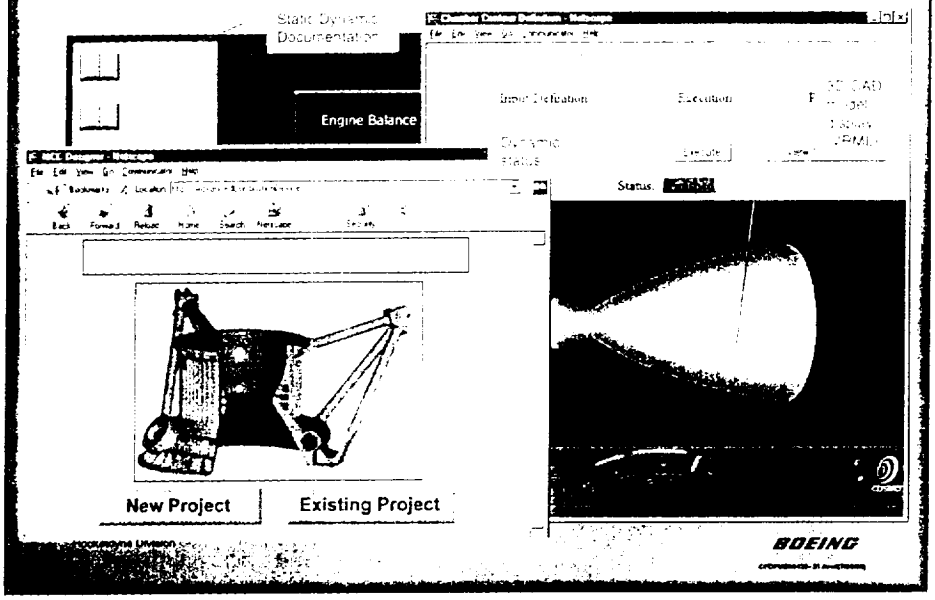
Rule-based System for Combustion Chamber Design



Integrated Design Systems Reduce Cost & Cycle Time for Engine Development

- **Synthesize MDO, ES and collaborative technologies into turnkey analysis and design systems**
  - User-oriented systems in language that user understands
  - Capture key engineering expertise
  - Reduce design and life cycle costs
  - Improve product quality
  - Reduce expertise level required by the user

Examples:

- **SEASHELL** (BIVDS)- Scramjet engine design
- **TOP** - Turbine optimization program
- **PNASH** - Pump network analysis shell
- **Turbine Information Powergrid**
- **CASINO** - Aerospike nozzle design

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Summary

- **The focus of the AA MDO team is to reduce product development cost**
  - Capture & automate best design & analysis practices
  - Increase availability of low-cost, high-fidelity analysis
- **Implement robust design to reduce costs associated with the Test-Fail-Fix cycle**
- **RD is currently focusing on several technologies to improve the design process**
  - Optimization and Robust Design
  - Expert & Rule-based Systems
  - Collaborative Technologies
  - MDO Algorithms
  - Internet infrastructure

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